A Similarity Solution for Gas Production from Dissociating Hydrate Accumulations

George J. Moridis and Matthew Reagan
Contact: George J. Moridis, 510/486-4746, gjmoridis@lbl.gov

RESEARCH OBJECTIVES

The main objective of this study is to demonstrate that the problem of single-well gas production from dissociating hydrate-bearing geologic systems accepts a similarity solution. Such solutions are invariant when plotted against the similarity variable r^2/t; can form the basis of simplified, yet robust, graphical methods to estimate gas production from natural gas hydrate accumulations; and can serve as a tool to test the validity and accuracy of numerical simulators.

APPROACH

This study was motivated by the realization that there is a direct analogy between the phases of a pure H_2O system and a composite CH_4-H_2O hydrate system. Following the approach used in the development of the H_2O-based systems, we used the Boltzman transformation to reduce the partial differential equations (PDEs) of fluid flow and heat transfer in a hydrate-bearing geologic system, the boundary conditions, and the initial conditions into a set of ordinary differential equations (ODEs) of a form entirely consistent with prior similarity solutions. The transformation was conducted without any thermophysical simplifications or reduction in the strong nonlinearities of the PDEs. To prove the existence of a similarity solution, the ability to transform the original equations into a form known to accept a similarity solution is a necessary and sufficient condition. Thus, it is not necessary to solve the transformed system of equations; rather, it suffices to solve the original (coupled and strongly nonlinear) PDEs, and to demonstrate the invariance of any of the parameters (e.g., pressure, temperature, phase saturations) with respect to the similarity variable $r/t^{1/2}$.

ACCOMPLISHMENTS

Using the TOUGH-Fx/Hydrate numerical simulator of system behavior in hydrate-bearing geologic media, we demonstrated that the problem of gas production from natural hydrate accumulations admits a similarity solution. We established that such similarity solutions apply to all methods of hydrate dissociation (i.e., depressurization, thermal stimulation, and the effect of inhibitors), both individually and in any combination.

SIGNIFICANCE OF FINDINGS

Because the problem admits a similarity solution, the distributions of any of the variables (e.g., pressure, temperature, phase saturation) are invariant when plotted against r^2/t. Therefore, a single set of results is sufficient to describe system behavior and performance at any time.

The similarity solution can provide a simple and robust tool for evaluating the production potential of hydrate deposits. To accomplish this, we can develop simple graphical solutions for very complex problems by obtaining a family of similarity graphs for different conditions, thus avoiding lengthy numerical simulations.

Additionally, because we showed that the hydrate problem has a similarity solution, any numerical solution must be invariant when plotted against r^2/t. This is a robust tool for evaluating the accuracy of any numerical simulator of hydrate behavior. If the simulator is inaccurate, then the solutions at different times will not coincide.

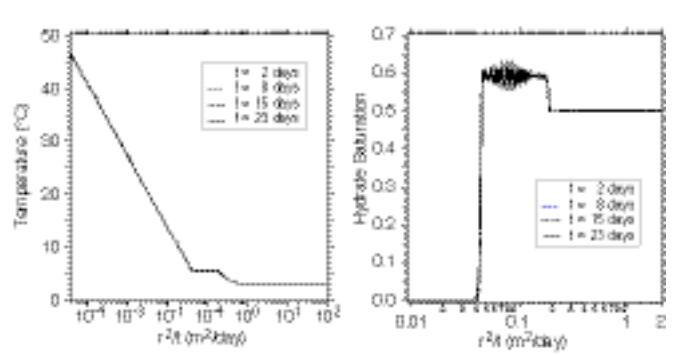

Figure 1. Numerically determined similarity solution of temperature and hydrate saturation vs. r^2/t at different times, for a 1-D radial problem of gas production from hydrate through thermal stimulation

RELATED PUBLICATION

Moridis, G.J., M. Kowalsky, and K. Pruess, TOUGH-Fx/HYDRATE User's Manual: A Code for the Simulation of System Behavior in Hydrate-Bearing Geologic Media. Berkeley Lab Report LBNL/PUB-3185, 2005.

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